

# Ultra Long Period Cepheids: a primary standard candle out to the Hubble flow.

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**Abstract** The cosmological distance ladder crucially depends on classical Cepheids (with  $P=3\text{--}80$  days), which are primary distance indicators up to 33 Mpc. Within this volume, very few SNe Ia have been calibrated through classical Cepheids, with uncertainty related to the non-linearity and the metallicity dependence of their period–luminosity (PL) relation. Although a general consensus on these effects is still not achieved, classical Cepheids remain the most used primary distance indicators. A possible extension of these standard candles to further distances would be important. In this context, a very promising new tool is represented by the ultra-long period (ULP) Cepheids ( $P \gtrsim 80$  days), recently identified in star-forming galaxies. Only a small number of ULP Cepheids have been discovered so far. Here we present and analyse the properties of an updated sample of 37 ULP Cepheids observed in galaxies within a very large metallicity range of  $12+\log(\text{O}/\text{H})$  from  $\sim 7.2$  to  $9.2$  dex. We find that

their location in the colour( $V\text{--}I$ )–magnitude diagram as well as their Wesenheit ( $V\text{--}I$ ) index-period (WP) relation suggests that they are the counterparts at high luminosity of the shorter–period ( $P \lesssim 80$  days) classical Cepheids. However, a complete pulsation and evolutionary theoretical scenario is needed to properly interpret the true nature of these objects. We do not confirm the flattening in the studied WP relation suggested by Bird et al. (2009). Using the whole sample, we find that ULP Cepheids lie around a relation similar to that of the LMC, although with a large spread ( $\sim 0.4$  mag).

**Keywords** Extragalactic Distance Scale – Variable stars –  $H_0$  measurement

## 1 Introduction

The two most popular routes to estimating the Hubble constant  $H_0$  involve the Cosmic Microwave Background (CMB) and the Supernovae type Ia (SNe Ia). The WMAP experiment (Komatsu et al. 2011) measures a precise time since recombination, and makes a strong case for a flat Universe. However, this measurement of the local expansion rate relies on the adopted cosmological model and on the priors (list of cosmological parameters) adopted in dealing with the CMB map. The SNe Ia provide an independent estimate of  $H_0$ . The absolute calibration of the SNe Ia luminosity peak is currently anchored to the Cepheid-based distances to a dozen nearby host galaxies, and for this reason Cepheids are the cornerstone for the absolute calibration of the extragalactic distance scale (e.g. Freedman et al. 2001; Saha et al. 2001). However, the universality of the Cepheid PL relation, and the possibility that the slope and/or the zero-point of the

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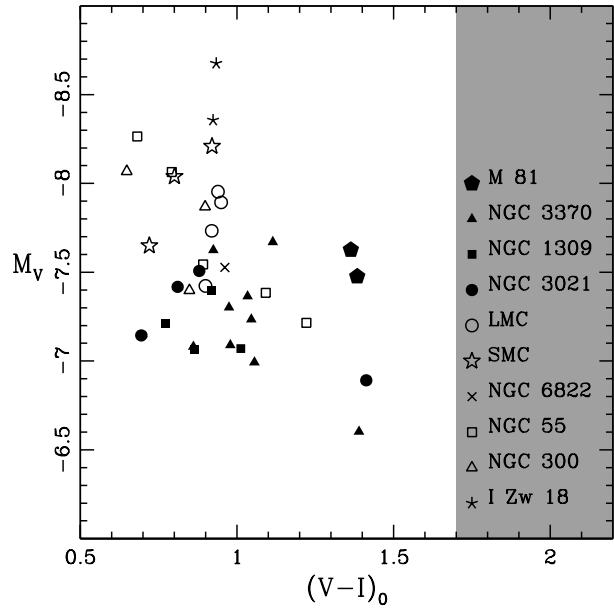
PL relation might depend on the chemical composition, have been lively debated for almost two decades (see e.g. Kennicutt et al. 1998; Fiorentino et al. 2002; Sakai et al. 2004; Marconi et al. 2005; Bono et al. 2008; Romaniello et al. 2008) with controversial results. No general consensus has been reached so far. The consequence of this uncertainty is that the most recent estimates of  $H_0$ , in spite of their very small formal accuracy ( $\sim 3\%$ ), might still be affected by systematic uncertainties of the order of 10%. To prove this statement, we emphasize that the values presented in this volume range from 62 to 74 Km/s Mpc. The above scenario can be summarized quoting Sandage et al. (2009): “... the universality of the PL relation is an only historically justified illusion.”

In this paper, we will discuss an on-going project devoted to the understanding of the nature of ULP Cepheids and their usefulness as stellar candles. In the next future, this possible new class of distance indicators will allow us to directly reach distances of cosmological interest, representing both an important alternative to SNe Ia and a better calibrator than classical Cepheids of this important secondary distance indicator as well as of other indicators. The reason of our interest in these stars is their intrinsic luminosity, which is 2-4 magnitudes brighter than typical classical Cepheids used so far to set the extragalactic distance ladder. Then, they allow us to extend the current observational limit (NGC 1309 is the farthest galaxy with identified classical cepheids and it is located at 33 Mpc, see Riess et al. 2009) up to 100 Mpc. Furthermore, the ESA astrometric satellite Gaia will provide trigonometric parallaxes at micro-arcsec accuracy, hence precise direct distances of the LMC and SMC ULP Cepheids. And last, but not least, the ULP’s potential is to be further enhanced by new generation ground-based telescopes such as the European Extremely Large Telescope (E-ELT, Tolstoy et al. 2010; Deep et al. 2011; Fiorentino et al. 2011), which can make the ULP Cepheids (observable up to 320 Mpc) the first primary distance indicator capable to directly measure  $H_0$  in “one-step”.

## 2 The Ultra Long Period sample

The recent identification of ULP Cepheids can be attributed to different observational biases conspiring to make them elusive for such a long time. In fact, they may have often escaped detection because of:

- the very long time baseline (up to few years) needed to well characterize their periods;



**Fig. 1** Colour–magnitude diagram for the ULP Cepheids observed so far for which V and I photometry is available in the literature. Distance modulus and reddening used to plot ULP Cepheids in this plane are reported in Table 1. Metal–rich galaxies ( $12+\log(\text{O}/\text{H}) \gtrsim 8.4$  dex or  $Z=0.008$ , i.e. LMC) have been highlighted with filled symbols.

- their very bright intrinsic luminosity that causes them to be saturated sources in the photometry of closely galaxies.

This is the case in the Magellanic Clouds whose ULP Cepheids are in fact very close to the saturation limit of the OGLE survey (Soszyński et al. 2008).

Bird et al. (2009) collected 18 ULP Cepheids, with period longer than 80 days, in six observed metal–poor ( $12+\log(\text{O}/\text{H}) \lesssim 8.4$  dex or  $Z=0.008^1$ ) star forming galaxies, namely the Magellanic Clouds, NGC 6822, NGC 55, NGC 300 and I Zw 18 (see Table 1). Using available V, I photometry they studied the ULP Cepheid location in the  $\log P$  vs V and I filters and the  $\log P$  vs the V–I Wesenheit index<sup>2</sup> index diagrams in comparison with classical Cepheids in the Small Magellanic Cloud (SMC). The authors noticed that this sample shows a large scatter around the relationships that hold for SMC classical Cepheids. They suggested that this scatter could be due to a possible flattening

<sup>1</sup> Assuming that the oxygen abundance is a very robust proxy of the iron abundance (i.e.,  $[\text{Fe}/\text{H}] = [\text{O}/\text{H}]$ ), we can use the following relation to convert  $12+\log(\text{O}/\text{H})$  in  $Z$ :  $Z=Z_\odot \times 10^{(\log(\text{O}/\text{H})-12+3.1)}$ . To compute the values in Table 1, we have assumed  $\log(\text{O}/\text{H})_\odot = -3.10$ ,  $Z_\odot=0.02$  and  $Y_\odot=0.27$ .

<sup>2</sup> The Wesenheit index is defined as  $W = I - 1.55 \times (V - I)$ , where V and I are the apparent magnitudes.

**Table 1** Compilation of ULP Cepheids observed in galaxies with a large range of metallicity. This table does not include 27 cepheids observed in NGC 4536 (4), NGC 4639 (2), NGC 5584 (7), NGC 4038 (8) and NGC 4258 (6) with period longer than 80 days for which the V and I photometry is not yet available (Riess et al. 2011).

Galaxy	Period day	V mag	V-I mag	$\mu_0$ mag	E(B-V) mag	Z	12+log(O/H) dex
18 ULP Cepheids compiled in Bird et al. 2009							
I Zw 18	130.3	23.96	0.96	31.30	0.03	$\sim 0.0004$	7.21 <sup>1</sup>
I Zw 18	125.0	23.65	0.97	31.30	0.03	$\sim 0.0004$	7.21 <sup>1</sup>
SMC	210.4	12.28	0.83	18.93	0.09	$\sim 0.002$	7.98 <sup>2</sup>
SMC	127.5	11.92	1.03	18.93	0.09	$\sim 0.002$	7.98 <sup>2</sup>
SMC	84.4	11.97	0.91	18.93	0.09	$\sim 0.002$	7.98 <sup>2</sup>
NGC 55	175.9	19.25	0.84	26.43	0.13	$\sim 0.003$	8.05 <sup>3</sup>
NGC 55	152.1	19.56	0.95	26.43	0.13	$\sim 0.003$	8.05 <sup>3</sup>
NGC 55	112.7	20.18	1.05	26.43	0.13	$\sim 0.003$	8.05 <sup>3</sup>
NGC 55	97.7	20.54	1.25	26.43	0.13	$\sim 0.003$	8.05 <sup>3</sup>
NGC 55	85.1	20.84	1.38	26.43	0.13	$\sim 0.003$	8.05 <sup>3</sup>
NGC 6822	123.9	17.86	1.40	23.31	0.36	$\sim 0.003$	8.11 <sup>4</sup>
NGC 300	115.8	20.13	0.97	26.37	0.10	$\sim 0.004$	8.25 <sup>5</sup>
NGC 300	89.1	19.71	1.02	26.37	0.10	$\sim 0.004$	8.25 <sup>5</sup>
NGC 300	83.0	19.26	0.77	26.37	0.10	$\sim 0.004$	8.25 <sup>5</sup>
LMC	118.7	11.99	1.12	18.50	0.14	$\sim 0.008$	8.39 <sup>6</sup>
LMC	109.2	12.41	1.07	18.50	0.14	$\sim 0.008$	8.39 <sup>6</sup>
LMC	98.6	11.92	1.11	18.50	0.14	$\sim 0.008$	8.39 <sup>6</sup>
LMC	133.6	12.12	1.09	18.50	0.14	$\sim 0.008$	8.39 <sup>6</sup>
19 ULP Cepheids compiled in this paper							
M 81	96.766	21.52	1.40	27.69	0.08	$\sim 0.013$	8.7 <sup>7</sup>
M 81	98.981	21.69	1.42	27.69	0.08	$\sim 0.013$	8.7 <sup>7</sup>
NGC 3370	80.85	26.002	0.90	32.13	0.03	$\sim 0.02$	8.82 (9.21) <sup>8</sup>
NGC 3370	81.04	25.895	1.01	32.13	0.03	$\sim 0.02$	8.82 (8.92) <sup>8</sup>
NGC 3370	83.28	27.010	1.43	32.13	0.03	$\sim 0.02$	8.82 (8.66) <sup>8</sup>
NGC 3370	86.33	25.892	1.07	32.13	0.03	$\sim 0.02$	8.82 (8.93) <sup>8</sup>
NGC 3370	88.25	26.112	1.01	32.13	0.03	$\sim 0.02$	8.82 (8.70) <sup>8</sup>
NGC 3370	88.54	25.667	1.15	32.13	0.03	$\sim 0.02$	8.82 (9.24) <sup>8</sup>
NGC 3370	96.49	25.522	0.96	32.13	0.03	$\sim 0.02$	8.82 (8.89) <sup>8</sup>
NGC 3370	96.82	26.286	1.09	32.13	0.03	$\sim 0.02$	8.82 (8.66) <sup>8</sup>
NGC 3370	98.72	26.034	1.08	32.13	0.03	$\sim 0.02$	8.82 (9.04) <sup>8</sup>
NGC 1309	82.13	26.481	0.90	32.59	0.04	$\sim 0.02$	8.90 (8.87) <sup>8</sup>
NGC 1309	82.38	26.246	0.81	32.59	0.04	$\sim 0.02$	8.90 (9.07) <sup>8</sup>
NGC 1309	89.03	26.625	1.05	32.59	0.04	$\sim 0.02$	8.90 (9.25) <sup>8</sup>
NGC 1309	97.89	26.201	0.95	32.59	0.04	$\sim 0.02$	8.90 (9.13) <sup>8</sup>
NGC 3021	82.66	25.913	0.73	32.27	0.013	$\sim 0.02$	8.94 (8.65) <sup>8</sup>
NGC 3021	88.18	26.884	1.45	32.27	0.013	$\sim 0.02$	8.94 (9.10) <sup>8</sup>
NGC 3021	90.73	25.735	0.92	32.27	0.013	$\sim 0.02$	8.94 (9.14) <sup>8</sup>
NGC 3021	95.91	25.756	0.85	32.27	0.013	$\sim 0.02$	8.94 (8.94) <sup>8</sup>

<sup>1</sup>Fiorentino et al. (2010), Contreras Ramos et al. (2011); <sup>2</sup> Peimbert and Torres-Peimbert (1976), Hilditch et al. (2005), Keller and Wood (2006); <sup>3</sup> Pietrzyński et al. (2006); <sup>4</sup> Pietrzyński et al. (2004); <sup>5</sup> Gieren et al. (2004), Gieren et al. (2005), Urbaneja et al. (2005); <sup>6</sup> Freedman et al. (1985), Pagel et al. (1978), Udalski et al. (1999); <sup>7</sup> Gerke et al. (2011); <sup>8</sup>Riess et al. (2009).

of the PL relations and in particular of the WP relations and they suggest that ULP Cepheids could be better standard candles than classical Cepheids. More recently, other 46 ULP Cepheids have been detected in predominantly metal-rich ( $12+\log(\text{O}/\text{H}) \gtrsim 8.4$  dex or  $Z=0.008$ ) galaxies where SNe Ia were observed. For 19 ULP Cepheids out of 46, V and I photometry is available in literature.

We considered the properties of the updated sample of ULP Cepheids (see Table 1). It is worth mentioning that the ULP sample is going to further increase in the next years thanks to the opportunity to follow up the surveyed galaxies to minimize the errors on the calibration of SNe Ia using classical Cepheids (Riess et al. 2011, and references therein). In fact, in this context 27 new objects have been observed and

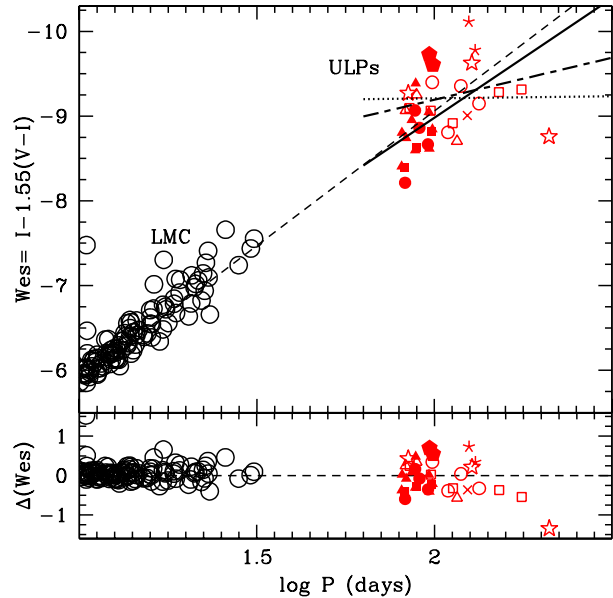
classified as ULP Cepheids with Wide Field Camera 3 on board HST. However, in the literature, only F160W photometry and V-I colour are available. Furthermore, we observed the Blue Compact Galaxy NGC 1705 with Gemini-South, for which a detailed star formation history is known through a careful analysis of UB-VIJH data taken with WFPC2, ACS and NICMOS on board of HST (Tosi et al. 2001; Annibali et al. 2003, 2009). In this galaxy, by analogy with I Zw 18, we expect to observe ULP Cepheids (in addition to classical Cepheids), given the occurrence of several stars with mass around and above  $15 M_{\odot}$  and thus to have the opportunity to constrain the ULP Cepheids evolutionary state (see Sect. 4), these results will be soon published (Fiorentino et al. in prep.). We have also obtained time on the Gemini-North telescope and on the Telescopio

Nazionale Galileo to follow up the most metal-poor ULP Cepheids found so far in I Zw 18 (Fiorentino et al. 2010) and a long period cepheid observed in UGC 9128 (or DDO 187 Hoessel et al. 1998). These two galaxies are the only ones containing ULP Cepheids that have a metallicity lower than the typical value for the SMC ( $12 + \log(\text{O}/\text{H}) \lesssim 8$  dex or  $Z=0.004$ ). On this basis they are crucial to constraints the evolutionary and pulsation models of ULP Cepheids (see Sect. 4).

In Fig. 1, the location in the colour-magnitude diagram of the whole sample collected in this paper is shown. In order to emphasize the metallicity dependence of the Cepheid location we have used empty and starred symbols for metal-poor galaxies and filled ones for metal-rich galaxies. With only a few exceptions and in spite of the large range of metallicity, most of the ULP Cepheids seem to occupy the same region of the instability strip (IS). Furthermore, the main difference between ULP Cepheids belonging to different galaxies seems to be the intrinsic luminosity, the metal-rich ULP Cepheids also being the fainter ones. These metal-rich ULP Cepheids also show shorter periods ( $P \lesssim 100$  days) than the metal-poor ones. In order to properly describe this behaviour, we are developing a full pulsation and evolutionary theoretical scenario for these very bright pulsators with metallicities ranging from  $Z=0.0004$  to  $Z=0.02$  taking advantage of our experience in modeling classical Cepheids (Bono et al. 1997; Fiorentino et al. 2002; Marconi et al. 2005).

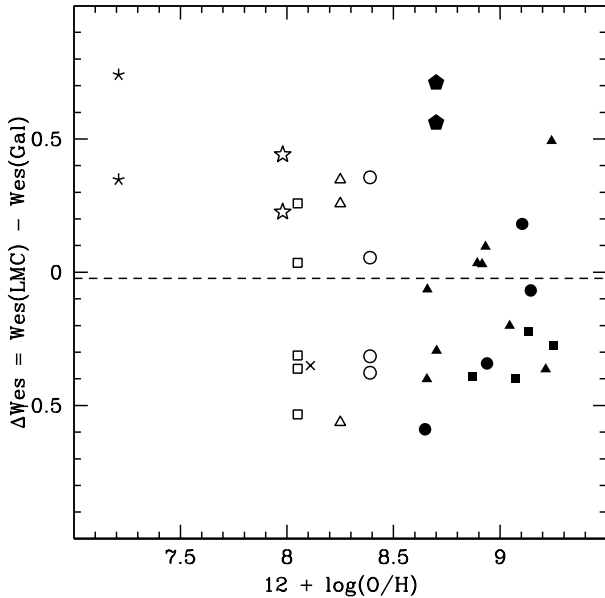
### 3 Period *vs* the Wesenheit index

The Cepheid distances are usually derived by means of the WP relation (Madore 1976; Fiorentino et al. 2007; Bono et al. 2008). This formulation of the more general PL relation has the advantage to be reddening-free by construction and to include the colour (and in turn the temperature) information for each individual star, defining a very tight relation. In their work, Bird et al. (2009) discussed the WP relation of the ULP sample and compared it to that of classical Cepheids in the SMC. They found that ULP Cepheids have a larger scatter ( $\sim 0.5$  mag) when compared with SMC classical Cepheids ( $\lesssim 0.08$  mag). They claim that this large scatter may depend on the poor ULP's sample used in their paper, suggesting that more observations are needed in order to collect a significant statistical sample that could compete with the accuracy reached by the OGLE III survey for the SMC (which includes 2626 fundamental mode Cepheids, Soszyński et al. 2010). Bird et al. (2009) also suggest that a metallicity dependence could exist and cause the large scatter observed



**Fig. 2** *Top-panel:* The  $\log P$  vs Wesenheit index in V and I bands. Black dots are the LMC classical Cepheids whereas red empty and filled dots are metal-poor and metal-rich ULP Cepheids recently observed (see Table 1, for details). Dashed line represents the classical Cepheid WP relation for the LMC extrapolated to long period range. Dotted line represent the flat slope suggested by Bird et al. (2009) using only the metal-poor sample. Dotted-dashed line represent the same linear fit excluding the very long period ULP Cepheid in the SMC (star). Solid line shows the fit obtained adding the whole sample collected in this paper. *Bottom-panel:* The residual to the LMC relation have been shown to highlight the significant spread at high luminosity. *Both-panels:* the symbol-code for ULP Cepheids is the same used in Fig. 1.

in the WP relation, as the investigated variables cover a metallicity range from  $12 + \log(\text{O}/\text{H}) = 7.22$  to  $8.39$  dex. However, they conclude that the sample is affected by distance uncertainty and that the metallicity effect can not be proven. Moreover, most of the variables used by Bird et al. (2009) are in galaxies with metallicities similar or poorer than SMC ( $Z=0.004$ ,  $12 + \log(\text{O}/\text{H}) = 7.98$  dex), so in a metallicity range where this dependence is expected to be small. The only exception is represented by the two ULP Cepheids recently discovered in the extremely metal-poor ( $Z=0.0004$ ,  $12 + \log(\text{O}/\text{H}) = 7.21$  dex) Blue Compact Dwarf galaxy I Zw 18 (Fiorentino et al. 2010, see Sect. 4 for details). They also notice that I Zw 18 Cepheids have the largest scatter in the PL plane in both V and I bands and, for this reason, they do not use them in their analysis. Concerning the metallicity effect on the WP relation, we note here that Bono et al. (2010) using updated theoretical models for classical Cepheids (Bono et al. 1999;



**Fig. 3** Metallicity–dependence of the Wesenheit index. The difference between the Wesenheit index, as defined in the LMC, and in the host galaxy is plotted against the metallicity  $[12 + \log(\text{O}/\text{H})]$ . The symbol–code is the same used in Fig. 1.

Fiorentino et al. 2002; Marconi et al. 2005) show that the WP relation in V and I bands is not supposed to be metal–dependent and that Marconi et al. (2010) predict an insensitivity to metallicity when the metallicity decreases below the typical SMC value. However, a recent application of the infrared surface brightness technique to Cepheids of SMC, LMC and the Galaxy shows an opposite effect (Storm et al. 2011).

In Fig. 2, we show the WP relation for the updated ULP sample in comparison with the LMC classical Cepheids, released from the OGLE III survey ( $\sim 1849$  stars pulsating in the fundamental mode, Soszyński et al. 2008). Using only galaxies with  $12 + \log(\text{O}/\text{H}) \leq 8.4$  dex, Bird and collaborators found an almost flat slope, i.e.  $\text{Wes}(\text{I}, \text{V}-\text{I}) = -9.12 - 0.05 \log P$  with  $\sigma = 0.36$  mag (dotted line in Fig 2). However, excluding from the fit the SMC cepheid with the longest period, we find  $\text{Wes}(\text{I}, \text{V}-\text{I}) = -7.21 - 0.99 \log P$  with  $\sigma = 0.34$  mag (dashed–dotted line in Fig. 2). If we include in the fit the ULP Cepheids in the metal–richer galaxies, approaching the solar metallicity such as NGC 1309, NGC 3370, NGC 3021 and M 81 (recently observed by Riess et al. 2009; Gerke et al. 2011), we see that a slope is drawn corresponding to  $\text{Wes}(\text{I}, \text{V}-\text{I}) = -3.68 - 2.66 \log P$  with  $\sigma = 0.34$  mag (solid line), which starts to resemble the Wesenheit index observed in the LMC, i.e.  $\text{Wes}(\text{I}, \text{V}-\text{I}) = -2.70 - 3.187 \log P$  with  $\sigma = 0.08$  mag (dashed line).

Our updated sample covers a larger metallicity range, with  $12 + \log(\text{O}/\text{H})$  going from 7.21 dex to 8.94 dex. Thus, we are able to extend the work presented in Bird et al. (2009) and to better investigate the possible metallicity effect on the Wesenheit index. We have computed the difference between the Wesenheit index expected for the LMC and the observed one. In Fig. 3 we show this difference versus the metallicity for each galaxy. For metal–rich ULP Cepheids, we have taken into account the metallicity gradient measured in the host galaxies (Riess et al. 2009) instead of using the mean metallicities. In order to do this we have estimated the distance of each ULP from the centre of the galaxy and then we have assigned to the star a metallicity value derived using the formula presented in Riess et al. (2009). In Table 1, we reported both the mean and the individual metallicity (in parenthesis) for each star. The derived metallicities span a larger range that goes from  $12 + \log(\text{O}/\text{H}) = 8.6$  to 9.2 dex.

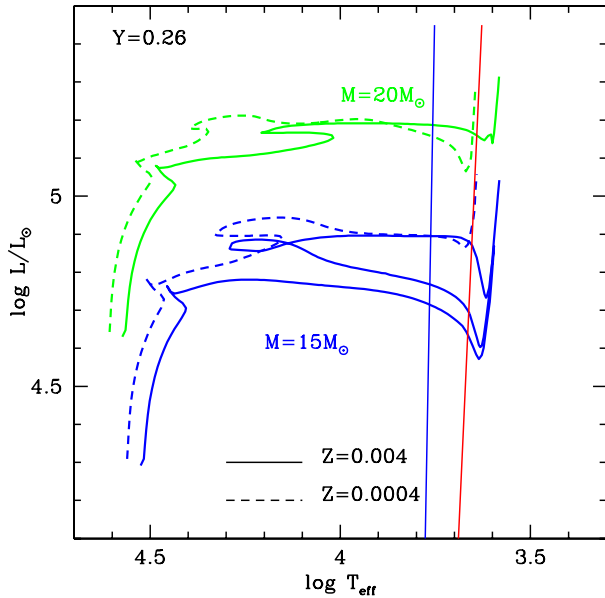
From Fig. 3 we can only draw some qualitative conclusions. In fact, we are aware that the “indirect” metallicity proxy  $[\text{O}/\text{H}]$  is not the best measurement we can use to identify the metallicity effect, and that individual spectroscopic measurements (Romaniello et al. 2008; Pedicelli et al. 2009) would be necessary to this purpose.

No significant trend with metallicity is observed. Indeed all the samples cluster around an almost zero average (dashed line in Fig. 3) apart from the ones of I Zw 18 and M 81 that could be affected by blending with blue and red stars respectively (Fiorentino et al. 2010; Gerke et al. 2011).

#### 4 Pulsation and evolutionary models in the low metallicity regime

The discovery of two bona-fide ULP Cepheids with periods of 125 and 130.3 days in I Zw 18 poses some problems on the theoretical interpretation of these objects. The ULP Cepheids lie in a region of the HR diagram where current stellar evolution models do not predict the existence of core-helium burning blue loops, the evolutionary phase which so far produces Cepheids.

As an example, in Fig. 4 we show the evolutionary tracks from Bertelli et al. (2009) for  $M = 15$  and  $20 M_{\odot}$  in the low metallicity regime, namely for  $Z = 0.004$  (or  $12 + \log(\text{O}/\text{H}) \sim 8$  dex, solid line) and  $Z = 0.0004$  (or  $12 + \log(\text{O}/\text{H}) \sim 7.2$  dex, dashed line). These masses bracket the luminosity observed for the ULP Cepheids in I Zw 18. We have also reported the red (cold) and blue (warm) theoretical boundaries of the pulsation IS as presented in Marconi et al. (2010). It is clear that



**Fig. 4** Evolutionary tracks for 15 and 20  $M_{\odot}$  from the Padua database (Bertelli et al. 2009) plotted in the Hertzsprung–Russell diagram. Solid lines represents a metallicity typical for SMC whereas dashed line represent the very low metallicity typical of I Zw 18. The two almost vertical solid lines represent the instability strip as computed using updated theoretical models “ad hoc” for I Zw 18 (Marconi et al. 2010).

the only evolutionary track that shows a “classical” blue loop crossing the IS is the track for 15  $M_{\odot}$  and  $Z=0.004$ . The remaining evolutionary tracks cross the IS only after, and not during, the central helium burning phase. This has some effect on the evolutionary times spent in the IS and in turn on the probability that we have to observe these objects. Here it is worth to mention that the blue loop phase has to be treated with caution. In fact, its occurrence is related to different physical parameters. The most important are: *i*) the chemical composition which influences the extension of the blue loop. The loop is more extended when the helium content increases (at fixed metallicity) whereas it is less extended when the metal content increases (at fixed helium content); *ii*) the mixing during the Hydrogen central burning that reduces the extension of the blue loop if its efficiency increases.

In this context the observation of pulsating objects can give sound constraints on the involved physical mechanisms, in particular when connected with the star formation history of the host galaxy. In fact, star counts are directly correlated to the evolutionary times spent in the different phases. The computations of new evolutionary models is in progress in order to provide firm constraints both on the evolutionary times and on the

inputs for our non-linear convective pulsation models. We note that the full understanding of the theoretical scenario in the metal-poor regime is particularly important. In fact, at these low metallicities ( $Z \lesssim 0.008$ ), theoretical models predict the long periods observed for ULP Cepheids only assuming stellar masses and luminosities significantly higher than that characterizing classical Cepheids. Therefore, a pure extrapolation of classical Cepheids properties such as the mass-luminosity relation and the inner structure seems not to hold for metal-poor ULP Cepheids pulsation models (see Marconi et al. 2010).

## 5 Conclusions

We have updated the sample of ULP Cepheids available in literature extending the covered metallicity range which now spans  $\sim 2$  dex, from  $12 + \log(\text{O}/\text{H}) = 7.23$  dex to 9.2 dex. The main results are the following:

- The observed properties, such as the location in the colour–magnitude diagram and the WP relation, suggest that they are the counterparts at high luminosity of the shorter–period ( $P \lesssim 80$  days) classical Cepheids.
- Using the whole updated sample, we do not confirm the flattening in the Wesenheit index suggested by Bird et al. (2009). Instead we find that:  
 $\text{Wes}(I, V-I) = -3.68 - 2.66 \log P$   
 with  $\sigma = 0.34$  mag. Then, these pulsators lie with a large spread ( $\sim 0.4$  mag) around a WP relation consistent within the errors with that of the LMC Cepheids.
- We have qualitatively investigated the metallicity dependence of the Wesenheit index derived from the V and I bands. We do not find a significant metallicity dependence in good agreement with the theoretical modelling of classical Cepheids (Bono et al. 2010). Thus, the metallicity differences do not seem to be the cause of the spread around the WP relationship. The cause could likely be the non–homogeneity and the poor statistic of the sample, but also mean magnitudes and colours not well determined.

Concluding, we suggest to follow up galaxies where ULP Cepheids have been observed and to perform variability studies in particular in the metal-poor range ( $12 + \log(\text{O}/\text{H}) \lesssim 8.4$  dex). A new homogeneous and larger sample will help us to understand the nature of these objects. In fact the observation of such massive objects (from 15 to 20  $M_{\odot}$ ) in the low metallicity regime poses some problems in their interpretation as blue–loop stars crossing the classical IS and their existence gives also some constrain to the internal structure

of these objects. On the other hand the construction of new accurate evolutionary and pulsation models for ranges of masses corresponding to very metal poor ULP Cepheids will allow us to understand the true status as these pulsators and to confirm their nature of cosmological standard candles.

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